# Rotor 28B

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## About

Rotor 28B is part of a research program to study the effects of aspect ratio, diffusion factor, and solidity on rotors. To do so, experimental studies have been conducted on a series of high-hub-tip-radius-ratio compressor stages representative of the middle and latter stages of axial-flow compressors. In fact, 14 middle stages were tested to assess the effects on performance of varying both diffusion through the rotor and stator blades and blade aspect ratio. Among these 14 stages, there are rotors 23B, 24A, 25A, 26B, 27A and 28B. Both the tip diameter and the hub-tip radius ratio were held constant throughout each stage at 50.8 centimeters and 0.8, respectively.

- Original technical report [(cite:britsch1979design>Britsch. «Design and overall performance of four highly loaded, high speed inlet stages for an advanced high-pressure-ratio core compressor » 1979. pdf)]:

```
@TechReport{britsch1979design,
  author           = {Britsch, Werner R. and Osborn, Walter M. and
Laessig, Mark R.},
  date             = {1979},
  institution      = {NASA Lewis Research Center Cleveland, OH, United
States},
  title            = {Effects of Diffusion Factor, Aspect Ratio, and
Solidity on Overall Performance of 14 Compressor Middle Stages},
  number           = {NASA-TP-1523},
  url              = {https://ntrs.nasa.gov/citations/19790025039},
}
```

- Picture :

https://catalog.archives.gov/id/17446213

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@Misc{brown1975records,
author   = {Brown, M.},
title    = {Rotor 28B - Stator 22. {R}ecords of the {N}ational {A}eronautics
and {S}pace {A}dministration, 1903 - 2006. {P}hotographs relating to agency
activities, facilities and personnel, 1975 - 2013},
note     =
{\href{https://catalog.archives.gov/id/17446213}{https://catalog.archives.gov/
id/17446213}, 1975 }, % for Fig. 1}
```

**Useful documents**

- downloadable models (Git project)
- NASA technical report (.pdf)
- geometrical parameters file (.csv), usable as input of OpenMCAD[(cite:Kojtych_2022_gene_aubes>Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. code en libre accès)] to generate reference blade models.

# Reference blade

The **reference blade** is defined with multiple-circular arc profiles[(cite:Crouse_1969_computer)] given in the original NASA report[(cite:britsch1979design)]. Corresponding models are computed with the open-

source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Geometry

The geometry of rotor 28B is described in the original NASA report by the following tables. The length are in centimeters and the angles in degrees.

TABLE 13. – BLADE GEOMETRY FOR ROTOR 28B

| RP | PERCENT SPAN | RADII RI | RO | BLADE ANGLES KIC | KTC | KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.400 | 25.400 | 64.08 | 54.88 | 45.13 | 2.47 | 0.057 |
| 1 | 5. | 25.191 | 25.146 | 63.64 | 54.10 | 43.52 | 2.63 | -0.606 |
| 2 | 10. | 24.952 | 24.892 | 63.17 | 53.28 | 41.95 | 2.80 | -0.901 |
| 3 | 15. | 24.701 | 24.638 | 62.75 | 52.52 | 40.44 | 2.99 | -0.920 |
| 4 | 30. | 23.905 | 23.876 | 61.79 | 50.77 | 36.55 | 3.56 | -0.401 |
| 5 | 50. | 22.831 | 22.860 | 60.68 | 48.52 | 30.86 | 4.23 | 0.375 |
| 6 | 70. | 21.757 | 21.844 | 59.54 | 46.14 | 24.17 | 4.95 | 1.054 |
| 7 | 85. | 20.971 | 21.082 | 58.68 | 44.18 | 18.04 | 5.39 | 1.282 |
| 8 | 90. | 20.730 | 20.828 | 58.38 | 43.17 | 14.75 | 5.53 | 1.112 |
| 9 | 95. | 20.503 | 20.574 | 58.08 | 41.90 | 10.38 | 5.59 | 0.775 |
| HUB | 100. | 20.320 | 20.320 | 57.82 | 40.76 | 5.60 | 5.66 | 0.057 |

| RP | BLADE THICKNESSES TI | TM | TO | AXIAL DIMENSIONS ZIC | ZMC | ZTC | ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.051 | 0.188 | 0.051 | 0.702 | 2.319 | 2.253 | 4.362 |
| 1 | 0.051 | 0.197 | 0.051 | 0.669 | 2.320 | 2.224 | 4.419 |
| 2 | 0.051 | 0.207 | 0.051 | 0.634 | 2.320 | 2.191 | 4.473 |
| 3 | 0.051 | 0.217 | 0.051 | 0.599 | 2.320 | 2.157 | 4.523 |
| 4 | 0.051 | 0.250 | 0.051 | 0.515 | 2.316 | 2.055 | 4.645 |
| 5 | 0.051 | 0.292 | 0.051 | 0.402 | 2.309 | 1.909 | 4.808 |
| 6 | 0.051 | 0.332 | 0.051 | 0.279 | 2.303 | 1.744 | 4.983 |
| 7 | 0.051 | 0.360 | 0.051 | 0.172 | 2.297 | 1.603 | 5.125 |
| 8 | 0.051 | 0.369 | 0.051 | 0.120 | 2.296 | 1.541 | 5.192 |
| 9 | 0.051 | 0.377 | 0.051 | 0.057 | 2.295 | 1.468 | 5.278 |
| HUB | 0.051 | 0.383 | 0.051 | -0.000 | 2.294 | 1.404 | 5.370 |

## Aerodynamic design

| | unit | value |
|---|---|---|
| **pressure ratio** | [-] | 1.399 |
| **mass flow** | [kg/s] | 9.46 |
| **tip speed** | [m/s] | 243.8 |
| **tip solidity** | [-] | 1.8 |
| **aspect ratio** | [-] | 0.8 |
| **number of blades** | [-] | 45 |
| **rotative speed** | [rad/s] | 960.28 |

## Material properties

The original material of the rotor 28B is not defined in the NASA report.

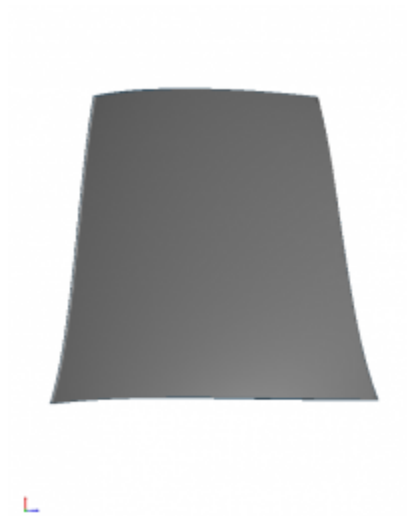
Considered properties: 200-grade maraging steel :

| | unit | value |
|---|---|---|
| **alloy** | [-] | 18-Ni-200-maraging |
| **Young's modulus** | [GPa] | 180 |
| **density** | [kg/m3] | 8000 |

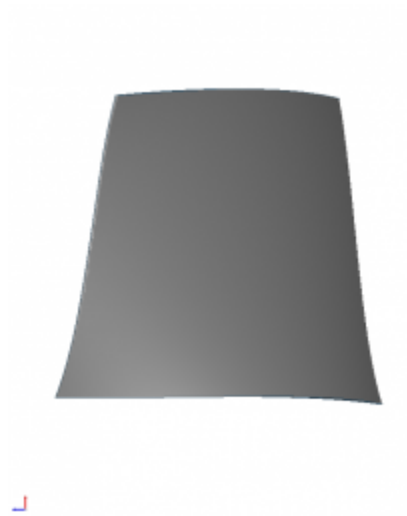
| | unit | value |
|---|---|---|
| **Poisson's ratio** | [-] | 0.3 |
| **yield stress** | [GPa] | 1.38 |

## CAD model

The CAD model is computed with the open source code OpenMCAD[(cite:Kojtych_2022_gene_aubes)].



pressure side



suction side

## Natural frequencies

First three natural frequencies (with clamped root) for the mesh computed with OpenMCAD[(cite:Kojtych_2022_gene_aubes)]:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 8345.01 | 1328.15 |
| 2 | 1T | 18238.58 | 2902.76 |
| 3 | 2B | 28121.40 | 4475.66 |

### Initial blade

The **initial blade** is defined with in-house LAVA parameters[(cite:Kojtych_2022_Methodology)] computed from the reference blade CAD model. The initial blade is usually used as starting point for an optimization process. Its geometry is similar to the one of the reference blade.

### Natural frequencies

First three natural frequencies (with clamped root)

- from the whole mesh:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 8253.97 | 1313.66 |
| 2 | 1T | 18215.39 | 2899.07 |
| 3 | 2B | 28231.55 | 4493.19 |

- from the reduced order model:

| Mode | Type | Natural angular frequency (rad/sec) | Natural frequency (Hz) |
|---|---|---|---|
| 1 | 1B | 8255.79 | 1313.95 |
| 2 | 1T | 18231.98 | 2901.71 |
| 3 | 2B | 28284.64 | 4501.64 |

Fichiers téléchargeables
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**Libre accès**

**lien vers le projet Git**

# À propos

Le rotor 28B fait partie d'un programme de recherche visant à étudier les effets de l’allongement, du facteur de diffusion et de la solidité des rotors. Pour ce faire, des études expérimentales ont été menées sur une série d'étages de compresseurs à fort rapport entre les rayons du moyeu et de la tête d’aube, représentatifs des étages moyens et avancés des compresseurs à flux axial. En effet, 14 étages intermédiaires ont été testés pour évaluer les effets sur les performances de la variation de la diffusion et de l’allongement des aubes. Parmi ces 14 étages, on trouve les rotors 23B, 24A, 25A, 26B, 27A et 28B. Le diamètre de l'extrémité des aubes et le rapport entre les rayons du moyeu et de la tête d’aube ont été maintenus constants tout au long de chaque étage à 50.8 centimètres et 0.8, respectivement.

- Rapport technique original [(cite:britsch1979design>Britsch. «Design and overall performance of four highly loaded, high speed inlet stages for an advanced high-pressure-ratio core compressor » 1979. pdf)]:

```
@TechReport{britsch1979design,
  author           = {Britsch, Werner R. and Osborn, Walter M. and
Laessig, Mark R.},
```

```
  date              = {1979},
  institution       = {NASA Lewis Research Center Cleveland, OH, United
States},
  title             = {Effects of Diffusion Factor, Aspect Ratio, and
Solidity on Overall Performance of 14 Compressor Middle Stages},
  number            = {NASA-TP-1523},
  url               = {https://ntrs.nasa.gov/citations/19790025039},
}
```

- Photographie :

https://catalog.archives.gov/id/17446213

```
@Misc{brown1975records,
author   = {Brown, M.},
title    = {Rotor 28B - Stator 22. {R}ecords of the {N}ational {A}eronautics
and {S}pace {A}dministration, 1903 - 2006. {P}hotographs relating to agency
activities, facilities and personnel, 1975 - 2013},
note     =
{\href{https://catalog.archives.gov/id/17446213}{https://catalog.archives.gov/
id/17446213}, 1975 }, % for Fig. 1}
```

### Documents utiles

- modèles téléchargeables (lien vers projet Git)
- rapport technique original

de la NASA (.pdf)

- fichier de paramètres géométriques (.csv), utilisable en entrée de OpenMCAD[(cite:Kojtych_2022_gene_aubes>Kojtych S., Batailly A. «OpenMCAD, an open blade generator: from Multiple-Circular-Arc profiles to Computer-Aided Design model» 2022. code en libre accès)] pour générer l'aube de référence

# Aube de référence

L'**aube de référence** est définie par des profils de type arcs circulaires multiples[(cite:Crouse_1969_computer>Crouse *et al*. «A computer program for composing compressor blading from simulated circular-arc elements on conical surfaces » 1969. NASA-TN-D-5437. pdf)], donnés dans le rapport technique original de la NASA[(cite:britsch1979design)]. Les modèles associés sont obtenus avec le code en libre accès OpenMCAD[(cite:Kojtych_2022_gene_aubes)].

## Géométrie

La géométrie du rotor 28B est décrite dans le rapport d'origine de la NASA par les tableaux suivants. Les grandeurs sont en centimètres et en degrés.

TABLE 13. – BLADE GEOMETRY FOR ROTOR 28B

| RP | PERCENT SPAN | RADII RI | RADII RO | BLADE ANGLES KIC | BLADE ANGLES KTC | BLADE ANGLES KOC | DELTA INC | CONE ANGLE |
|---|---|---|---|---|---|---|---|---|
| TIP | 0. | 25.400 | 25.400 | 64.08 | 54.88 | 45.13 | 2.47 | 0.057 |
| 1 | 5. | 25.191 | 25.146 | 63.64 | 54.10 | 43.52 | 2.63 | -0.606 |
| 2 | 10. | 24.952 | 24.892 | 63.17 | 53.28 | 41.95 | 2.80 | -0.901 |
| 3 | 15. | 24.701 | 24.638 | 62.75 | 52.52 | 40.44 | 2.99 | -0.920 |
| 4 | 30. | 23.905 | 23.876 | 61.79 | 50.77 | 36.55 | 3.56 | -0.401 |
| 5 | 50. | 22.831 | 22.860 | 60.68 | 48.52 | 30.86 | 4.23 | 0.375 |
| 6 | 70. | 21.757 | 21.844 | 59.54 | 46.14 | 24.17 | 4.95 | 1.054 |
| 7 | 85. | 20.971 | 21.082 | 58.68 | 44.18 | 18.04 | 5.39 | 1.282 |
| 8 | 90. | 20.730 | 20.828 | 58.38 | 43.17 | 14.75 | 5.53 | 1.112 |
| 9 | 95. | 20.503 | 20.574 | 58.08 | 41.90 | 10.38 | 5.59 | 0.775 |
| HUB | 100. | 20.320 | 20.320 | 57.82 | 40.76 | 5.60 | 5.66 | 0.057 |

| RP | BLADE THICKNESSES TI | BLADE THICKNESSES TM | BLADE THICKNESSES TO | AXIAL DIMENSIONS ZIC | AXIAL DIMENSIONS ZMC | AXIAL DIMENSIONS ZTC | AXIAL DIMENSIONS ZOC |
|---|---|---|---|---|---|---|---|
| TIP | 0.051 | 0.188 | 0.051 | 0.702 | 2.319 | 2.253 | 4.362 |
| 1 | 0.051 | 0.197 | 0.051 | 0.669 | 2.320 | 2.224 | 4.419 |
| 2 | 0.051 | 0.207 | 0.051 | 0.634 | 2.320 | 2.191 | 4.473 |
| 3 | 0.051 | 0.217 | 0.051 | 0.599 | 2.320 | 2.157 | 4.523 |
| 4 | 0.051 | 0.250 | 0.051 | 0.515 | 2.316 | 2.055 | 4.645 |
| 5 | 0.051 | 0.292 | 0.051 | 0.402 | 2.309 | 1.909 | 4.808 |
| 6 | 0.051 | 0.332 | 0.051 | 0.279 | 2.303 | 1.744 | 4.983 |
| 7 | 0.051 | 0.360 | 0.051 | 0.172 | 2.297 | 1.603 | 5.125 |
| 8 | 0.051 | 0.369 | 0.051 | 0.120 | 2.296 | 1.541 | 5.192 |
| 9 | 0.051 | 0.377 | 0.051 | 0.057 | 2.295 | 1.468 | 5.278 |
| HUB | 0.051 | 0.383 | 0.051 | -0.000 | 2.294 | 1.404 | 5.370 |

## Caractéristiques aérodynamiques

| | **unités** | **valeurs** |
|---|---|---|
| **taux de compression** | [-] | 1,399 |
| **débit massique** | [kg/s] | 9,46 |

| | unités | valeurs |
|---|---|---|
| **vitesse en tête** | [m/s] | 243,8 |
| **solidité en tête** | [-] | 1,8 |
| **allongement** | [-] | 0,8 |
| **nombre d'aubes** | [-] | 45 |
| **vitesse de rotation** | [rad/s] | 960,28 |

## Propriétés matériau

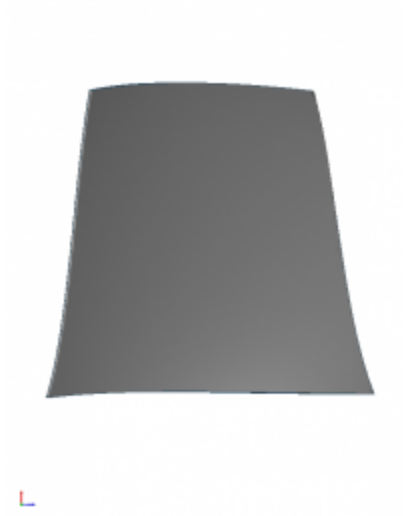
Le matériau original du rotor 28B n'est pas défini dans le rapport de la NASA.

Propriétés considérées : un acier maraging de grade 200 :

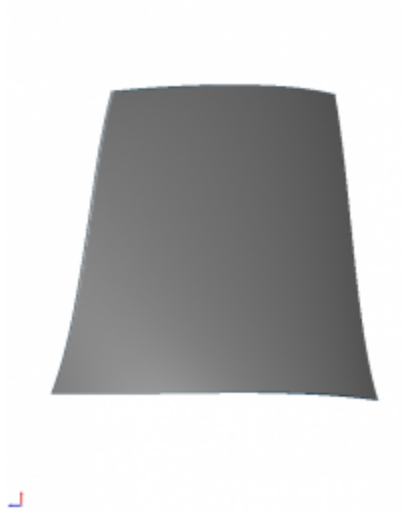
| | unité | valeurs |
|---|---|---|
| **alliage** | [-] | 18-Ni-200-maraging |
| **module d'Young** | [GPa] | 180 |
| **masse volumique** | [kg/m3] | 8000 |
| **coefficient de Poisson** | [-] | 0,3 |
| **limite élastique** | [GPa] | 1,38 |

## Modèle CAO

Le modèle CAO est obtenu avec OpenMCAD[(cite:Kojtych_2022_gene_aubes)].



intrados



extrados

### Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastrés) pour le maillage obtenu avec OpenMCAD[(cite:Kojtych_2022_gene_aubes)] :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 8345,01 | 1328,15 |
| 2 | 1T | 18238,58 | 2902,76 |
| 3 | 2F | 28121,40 | 4475,66 |

## Aube initiale

L'**aube initiale** est définie par des paramètres spécifiques au LAVA[(cite:Kojtych_2022_Methodology>Kojtych S. *et al*. «Methodology for the Redesign of Compressor Blades Undergoing Nonlinear Structural Interactions: Application to Blade-Tip/Casing Contacts » 2022. Journal of Engineering for Gas Turbines and Power, Vol. 145, No. 5. pdf)] obtenus à partir du modèle CAO de l'aube de référence. L'aube initiale est classiquement utilisée comme point de départ dans le cadre de procédures d'optimisation; sa géométrie est similaire à celle de l'aube de référence.

### Fréquences propres

Fréquences des trois premiers modes (noeuds du pied d'aube encastrés),

- pour le maillage complet :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 8253,97 | 1313,66 |
| 2 | 1T | 18215,39 | 2899,07 |
| 3 | 2F | 28231,55 | 4493,19 |

- pour le modèle réduit :

| Mode | Type | Pulsation propre (rad/sec) | Fréquence propre (Hz) |
|---|---|---|---|
| 1 | 1F | 8255,79 | 1313,95 |
| 2 | 1T | 18231,98 | 2901,71 |
| 3 | 2F | 28284,64 | 4501,64 |

</tabs>

Document issu de la page wiki:
**https://lava-wiki.meca.polymtl.ca/public/modeles/rotor_28b/accueil?rev=1679280370**

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